RESEARCH HIGHLIGHT

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ASSESSMENT OF SUITE COMPARTMENTALIZATION AND DEPRESSURIZATION IN NEW HIGH-RISE RESIDENTIAL BUILDINGS

INTRODUCTION

The provision of airtight interior and exterior partitions, or ***compartmentalization***, of individual suites and the installation of in-suite ventilation systems represent two improvements in the design and construction of multi-unit residential buildings (MURBs) that can improve the overall performance of this class of building.

Compartmentalization coupled with the provision of in-suite ventilation can reduce vertical and horizontal air movement through buildings, limit indoor-outdoor air exchange, reduce space heating costs, and increase comfort by providing better control of indoor temperature and humidity conditions. The concept of compartmentalization is also complementary to, and reinforces, fire and smoke control measures. Well-sealed apartments may also appeal to occupants as odour (tobacco smoke and cooking) and noise transfer between apartments may be significantly reduced.

However, one of the technical challenges of this approach concerns the provision of make-up air for in-suite exhaust-only appliances. Traditionally, make-up air has been provided by leakage in both the interior and exterior partitions and the operation of central corridor ventilation systems. If the partitions (including the corridor-to-suite door) were to be air sealed, there is a concern that there would be insufficient make-up air to allow for the proper operation of in-suite exhaust. The extent to which suites can be made to be airtight and the potential impact of suite airtightness on the performance of in-suite exhaust systems has not been explored. Thus the need for, and quantities of, make-up air for the individual suites of apartment buildings is not yet well understood.

To develop a better awareness of the potential make-up air requirements of well-sealed suites, CMHC initiated a research project to explore the air leakage characteristics, ventilation system performance and pressure diagnostics in eight suites of three recently constructed multi-unit residential buildings. All testing was done under mid-winter conditions in Toronto, Ontario.

METHODOLOGY

Determination of Air Leakage Characteristics

Air tightness testing was performed in eight suites in three buildings to characterize the equivalent leakage area at 10 Pa pressure (ELA at 10 Pa), normalized leakage area (NLA at 10 Pa), air change per hour (ACH at 50 Pa) and normalized flow rate at 75 Pa pressure. The testing was conducted using a modified approach to CAN/CGSB 149.1 "*Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method.*" The apartments were drywalled but were at various stages of trim and finish.

Air Flow Characteristics of In-Suite Exhaust Appliances and Resultant Suite Depressurization

The exhaust airflow capacities of in-suite exhaust appliances were measured using a hot wire anemometer or an air flow hood. The relative pressures induced by the operation of the exhaust fans on the suites with respect to outdoors and the adjacent corridors were measured by a digital pressure gauge with a wind averaging function. This testing also allowed for an assessment of the extent to which exhaust fans "competed" for indoor air.

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Corridor Pressurization and Air Flow Testing

Tests were conducted in one building to characterize the pressure differences between the suites and common corridors induced by the corridor ventilation system on the 2nd floor and 29th floor with the corridor ventilation systems on and off. On the 29th floor, the testing was repeated after all suite doors were taped off to assess the impact of sealing suites from the corridors.

OBSERVATIONS

Air Leakage Characteristics of Apartments

Table 1 provides the results of the air leakage testing in the eight suites tested. The air leakage data represent the sum of the leakage areas of **both** the exterior envelope and interior partitions (walls, doors, ceilings and floors).

For all suites, one of the largest leakage areas was around the suite entry door from the common corridor. In general, it appeared there was as much leakage from the corridor and adjacent suites as there was from outdoors although this was not confirmed by quantitative testing. There was noticeable leakage around plumbing and electrical penetrations through party walls between the suites and common corridors. This could also be the result of air leakage under and over bottom and top wall plates and around various building mechanical and electrical services. In Building 2, apartment 114, there was significant leakage around the two patio doors at the junction between the frame and sashes of the fixed and operable glazed units. This was the only apartment to have two patio doors and coincidently had the worst air leakage characteristics in the sample set.

Table 1: Air Leakage Characterization Test Results

Building/Apartment No.	ACH @ 50 Pa	ELA cm^2 @10 Pa	NLA cm^2/m^2 @ 10 Pa	Normalized Flow Index $L/s/m^2$ @ 75 Pa
Building 1/303	1.23	74	0.26	0.47
Building 1/2402	2.52	456	1.03	0.78
Building 1/2401	3.12	407	1.01	0.92
Building 1/2502	1.19	272	0.61	0.35
Building 2/114	3.16	318	1.19	1.01
Building 2/1006	2.62	138	0.77	0.72
Building 2/1506 (Corridor door taped)*	2.13	144	0.80	0.55
Building 3/1913 (As Is)	2.46	221	0.82	0.76
Building 3/1913 (Corridor door taped)	1.44	129	0.48	0.44

(ACH: air changes per hour; ELA: equivalent leakage area; NLA: normalized leakage area)

* *Note: Tape was applied as the door sill had not been installed at the time of the test.*

Table 2: Exhaust Fan Performance and Apartment Depressurization

Building/Apartment No.	Bath (L/s)	Range (L/s)	Dryer (L/s)	Pressure to Outside All Fans On
B/303	29, 29	18**	49	53 Pa
B/2402	24, 33*	101	57	25 Pa
B/2401	33*, 35*	92	47	21 Pa
B/2502 ***	-	-	-	-
C/114	31	113	61	25 Pa
C/1006	35, 35	64	47	50 Pa
C/1506 ***	-	-	-	-
D/1913 (Door As Is)	33, 38	49	52	35-40 Pa
D /1913 (Door sealed)	33, 38	47	52	65-75 Pa

* *Fan grilles not on*

** *Range hood not working properly*

*** *Fans not operational on day of test*

Note: In all cases the pressure outside was higher relative to inside, that is, the apartments were depressurized.

In-Suite Exhaust Appliance Air Flow and Resultant Suite Depressurization

The measured air flows of the in-suite exhaust appliances are shown in Table 2. The degree to which the suites were depressurized relative to outdoors under the combined operation of the exhaust fans in each of the suites tested is also provided. All suites except C 114 had two bathroom exhaust fans.

It was noted that the measured performance of the exhaust appliances was, for the most part, less than the design capacity called for on the construction drawings and the equipment specifications. Table 2 also shows that the simultaneous operation of in-suite exhaust appliances can severely depressurize the suites. Table 3 shows the results of more detailed testing of exhaust fan performance and suite depressurization in one suite when its corridor door was temporarily sealed representing the "worst-case" condition with respect to depressurization. Table 3 shows that the air flow capacities of the bathroom exhaust fans are greatly reduced when the range hood and clothes dryer are operating.

Table 3: Exhaust Fan Performance at Building 3 Apartment 1913 (Door weather-stripped) at Various Operating Points

Operating Mode	Bathroom Fan (L/s)	Range Hood (L/s)	Dryer (L/s)	Pressure to Outside	Pressure to Hall
All fans on	7, 17	40	42	65 to 75 Pa	80 Pa
Bath Fans only	33, 38	-	-	20 to 25 Pa	30 to 40 Pa
Dryer only	-	-	52	15 to 25 Pa	40 Pa
Range only	-	47	-	15 to 30 Pa	20 to 25 Pa
Dryer and Range on	-	42	45	50 to 60 Pa	65 to 70 Pa

Note: The range of pressures noted is due to gusting winds; it was very difficult to get steady pressure readings even with the time-averaged function. In all cases the apartments were at a lower negative pressure with respect to the corridor and outside.

Characterization of the Pressure Differences Between Apartments and Corridors Induced by the Corridor Ventilation System

Table 4 shows the results of the pressure mapping done on the upper and lower floor corridors of building 1 with the corridor air ventilation systems operating and when they were shut down.

With the corridor ventilation systems off, the lower floor suites and corridor were under a negative pressure with respect to outdoors while the upper floor suites and corridor were at a higher pressure relative to outdoors. This was due to the stack and wind pressures acting on the building. When activated, the corridor air system could not maintain positive pressure in the corridor relative to the suites on the second floor at all times even though the outdoor temperature was only 0°C. Taping the apartment to corridor doors on the upper floor (simulating weather-stripping) increased the pressure difference across the doors by 10 to15 Pa. This demonstrates that it would be possible to achieve corridor pressurization with reduced airflow rates if the suite-to-corridor doors were weather-stripped.

Table 4: Pressures Induced by Corridor Ventilation System (Building 1)

Condition	Air Pressure Differential Corridor to Outside	Air Pressure Differential Corridor to Apartment
29th Floor - Both Corridor Systems On	35 to 45 Pa	30 to 35 Pa
29th Floor - Upper Corridor System Off	25 to 30 Pa	20 to 25 Pa
29th Floor - Both Corridor Systems Off	10 to 20 Pa	10 to 15 Pa
29th Floor - Doors Taped, All Systems Off	5 to 10 Pa	15 to 20 Pa
29th Floor - Doors Taped, Lower System On, Upper Off	15 to 25 Pa	25 to 30 Pa
29th Floor - Doors Taped, Both Systems On	30 to 35 Pa	40 to 50 Pa
29th Floor - Doors Taped, Corridor Fans On, Exhaust Fans in One Apartment "On"	30 to 45 Pa	75 Pa
2nd Floor - Both Corridor Systems On	5 to 10 Pa	3 to -5 Pa
2nd Floor - Lower Corridor System On	5 to 10 Pa	3 to -5 Pa
2nd Floor - Corridor Systems Off	-30 to -40 Pa	-3 to -5 Pa

Note: "-" denotes suite being positively pressurized relative to the corridor in column 3

CONCLUSIONS

The key findings of the project include the following:

- The suites in new high-rise residential buildings can be relatively airtight but leakage still occurs through both interior and exterior partitions. The normalized leakage areas of the apartments tested were very close to the stringent airtightness requirements of the R-2000 energy efficiency house program.
- The actual airflow performance of the exhaust appliances was less than that specified. Higher-than-anticipated static pressure in the exhaust duct systems as well as adverse indoor-outdoor pressure regimes may be to blame.
- The operation of in-suite exhaust fans created a significant negative pressure in the suites tested. The resultant depressurization temporarily undermines the performance of in-suite exhaust fans as they are forced to "compete" for air. While the problem would be temporary and the suite occupants unlikely to notice the small decrease in exhaust performance, the potential severity of the depressurization could cause problems with the venting of some types of combustion appliances if installed.
- If combustion appliances are not installed within suites, it is unclear if the temporary depressurization of suites by in-suite exhaust appliances represents a problem or not.
- Corridor air ventilation systems could operate at reduced air flow volumes but could better contain suite odours if the suite to corridor doors were to be weatherstripped.

Implications for the Housing Industry

Suites in multi-unit residential buildings can be built to be relatively airtight. This has positive implications with respect to the overall performance of multi-unit residential buildings. However, the provision of relatively well-sealed suites cannot be done in isolation. Consideration must be given to in-suite ventilation, make-up air issues, suite depressurization tolerances and combustion appliance safety.

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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